SYNTHESIS AND CHARACTERIZATION OF POLYMERIC COMPOSITES FOR ELECTRICAL ENGINEERING APPLICATIONS

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

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Certificate

I hereby declare that the short synopsis "SYNTHESIS AND CHARACTERIZATION OF POLYMERIC COMPOSITES FOR ELECTRICAL ENGINEERING APPLICATIONS" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Electrical Engineering under Department of Electrical and Electronics Engineering, faculty of Engineering & Technology of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2022-2023. It is a bona fide record of original work carried out under the supervision of Dr. Anita Khosla, Professor, Department of Electrical and Electronics Engineering along with Dr. Aftab Alam, Associate Professor, Department of Polymer Technology, Delhi Skill & Entrepreneurship University, Guru Nanak Dev DSEU Rohini Campus, Sector-15, Rohini, Delhi, India and Dr. Pradeep K. Varshney, Professor, Department of Sciences, Manav Rachna University, Faridabad, Haryana, India and has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that short synopsis is plagiarism free and proof has been submitted.

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ABSTRACT

Majority of industrial consumption involving polymeric materials in electrical engineering field are insulating, energy storage, conducting, semiconducting and optoelectronics. Now a days, in advanced electrical power system and process control industry, polymeric materials have emerged as a potential substitute for insulation and dielectric application owing to its inherent superior electrical, mechanical and chemical property. Consequent upon some structural modification at molecular level, several electrical characteristics of polymeric composite such as insulating, dielectric, piezoelectricity, pyroelectricity, electro-photo-sensitivity, photo-emission, volume charge, induced & permanent electric dipole and electric charge movement phenomena etc. can be improved to a great extent to make it suitable for a specific industrial application. These materials have been replacing the conventional electrically active materials in the real-world applications such as switches, insulators, isolators, transducers, photo voltaic panels, process sensors, opto-couplers, capacitive or inductive touch screen, field emission displays, captative-electrolytes, electromagnetic shielding and polymeric batteries etc.

Emergence of the electrical and electronics industry and polymers as a new class of materials are both modern phenomena. With advent of technology and newer polymeric materials and its composites of high performance, entire landscape in industry has changed, this has created a favorable environment for research and development in this area. The scope of the present research work is synthesis, characterization, study and analysis of environment friendly polymeric composite for electrical engineering application. The composites of polyethylene and polypropylene materials reinforced with filler of inorganic and/or organic nature will be synthesized and studies of its electrical, mechanical, morphological and chemical properties will be carried out to optimize the content of its fillers for optimal electrical behavior. Comprehensive studies on relationship of fillers with transformed electrical, physical, mechanical and thermal properties of newly developed polymeric composites will be done and analysis of fillers content in polymeric matrix materials will also be carried out so that suitable applications of newly developed polymeric composites in electrical field can be explored.

Key words: -

Dielectric, Electrical insulation, Fillers, Polymeric composites, Polyethylene, Polypropylene.

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1. Introduction.

The word Polymer is derived from the two Greek words “poly” (meaning “many”) and “mer” (meaning “unit”), these materials are high molecules weight compound made of long chain of several similar or different smaller units or molecules known as monomeric compound, bind together in a chemical reaction called Polymerization. Because of its versatile characteristics and ability to perform varied functions, polymeric materials are increasingly and more frequently found to be replacing the conventional materials in wide range of electrical and other engineering applications. Few significant characteristics of interest possessed by these materials are their inherent electrical insulating property, deeply bound electric charge, permanent and induced electric dipole, piezoelectricity, pyroelectricity, photoemission, photoconductivity etc.

Despite of possessing such amazing and noteworthy electrical characteristics, polymers were considered as relatively weaker material in terms of load bearing properties at raised temperatures. This limited the use of polymers in electrical engineering field to non-load bearing and general-purpose applications only. Their utility as insulation materials too were limited because of requirement to increase the thickness of insulation material to cater for increase in higher operating voltages. Simply, increasing the thickness of insulating material to accommodate the elevated voltage level is not a practical and feasible solution for application in high power electrical components.

Miniaturization of electrical & electronic components at industrial scale and emergence of polymeric hybrid composite as new class of material, both has emerged as new opportunity for the researchers to tweak the ability/characteristics of polymers at molecular level such as to eliminate the features not desirable for intended application. Experimental engineering research to find a completely new electrical engineering material which can withstand high dielectric/electric stress, possess high thermal conductivity, chemical and mechanical stability even at lower thickness and weight is not a distant dream now a days. Essential need of the present-day research work is to formulate a low cost, lightweight, renewable yet superior substitute for electrical engineering application.

1.1 A brief description of polymeric materials in engineering and its classification.

Based on the key factors, for the ease of study, all the polymeric materials have been classified into following several broad categories as mentioned in figure-1.

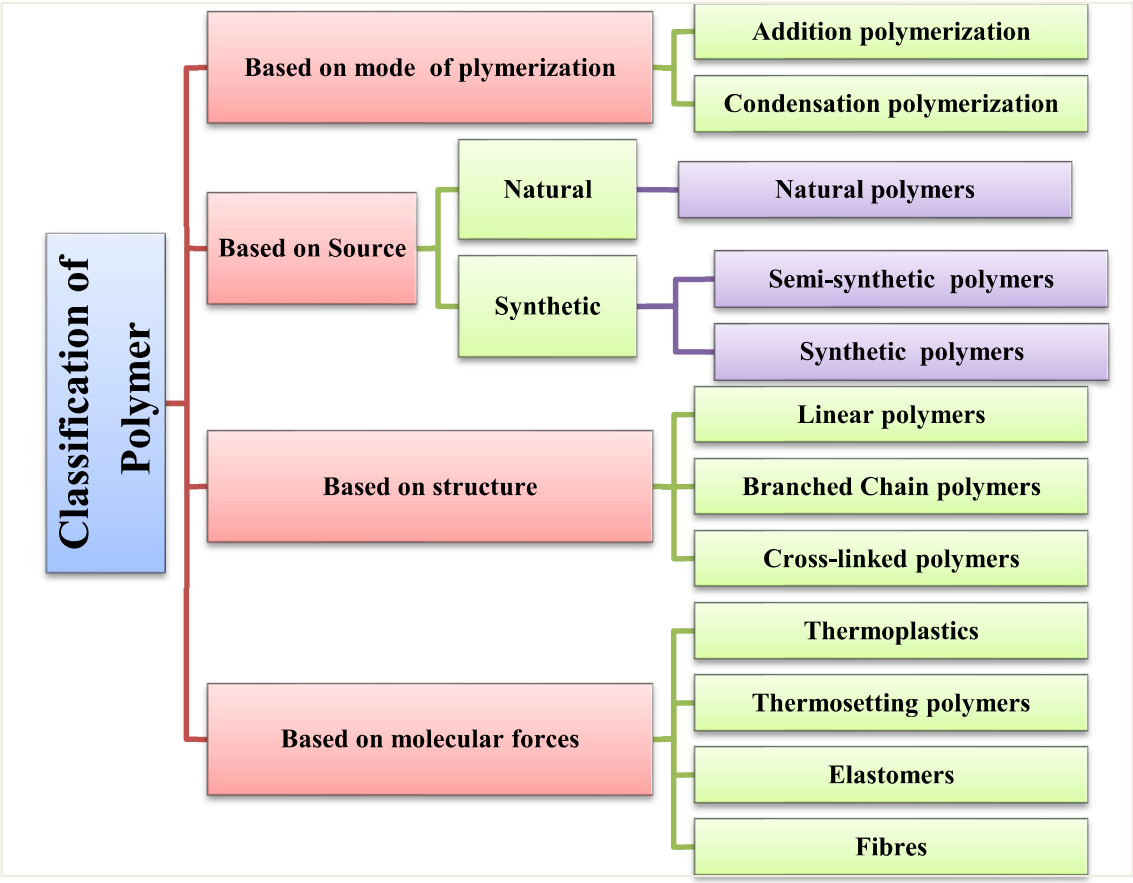

Figure 1. Broad classification of polymers as engineering material.

Performance of virgin polymer can be enhanced by additives and reinforcing agents such as fibers and fillers, this augments its versatility and superiority far beyond the one provided by individual polymers, such new form of polymers are known as polymeric blends or composites. To present a brief idea of such polymeric materials, brief descriptions of few relevant categories of polymeric materials are presented in the following paragraph.

❖ **Natural Polymeric materials** – These are derived from naturally available materials. Few examples are cotton, flax, silk, wool, leather, rayon, DNA, Protein etc.

❖ **Synthetic Polymeric materials –** These are artificially synthesized from monomer compounds. Few examples are polyethylene, polypropylene, polybutene, epoxy resins, rubber, nylon, PVC, etc.

❖ **Natural and Biodegradable polymeric materials –** These are new class of polymers which are less expensive, environmentally friendly and leaves very less or no impact on the environment on disposal. Although they are environment friendly but they exhibit relatively weak mechanical and thermal properties. Examples are corn starch and cellulose.

A variety of natural and synthetic polymeric material can be further classified into following three categories:

❖ **Elastomers –** These are highly elastic materials having viscous characteristics due to long chains and slightly cross-linked molecular structure, these materials have capability to recover their original shape after being stretched or distorted, such as rubber, neoprene, EPDM and isoprene.

❖ **Thermoplastics –** These polymers are characterized by their ability of plasticity wherein they can be repeatedly softened on heating or hardened on cooling. This material possesses moderately strong intermolecular force falling between elastomers and fibers which enable these polymers to be given shape or moulded very easily. Few examples are polythene, polypropylene, polystyrene, polyvinyl, etc.

❖ **Thermosetting –** These polymers are characterized by their ability of rigidness wherein they can be shaped/moulded on heating during their formation stage, they become hardened while being in hot stage only, thereafter they cannot be reshaped or re-moulded even after reheating. Such material possesses strong intermolecular force due to cross-linking of molecules by covalent bonds which prevents them from re-molding or re-shaping at later stage. Few examples are Bakelite, melamine-formaldehyde, urea-formaldehyde resin, cotton, flax, silk, wool, cellulose, leather, rayon, etc.

Plastindia Foundation an apex body of organization, associations and institution from the

Indian polymeric field in its report "Plastic Industry status report 2021-22 & 1H 2022-23" (Plastindia Foundation managing Committee 2021-22, 2023) presented a consolidated data which reported the global production of polymers in the year 2020-21 to be 367 million tons (Figure-2). In the following year 2021-22, United States of America (USA) remained at the first place in per capita plastic consumption whereas India remained at a very distant place with per capita consumption equal to about half of the global average (Figure-3).

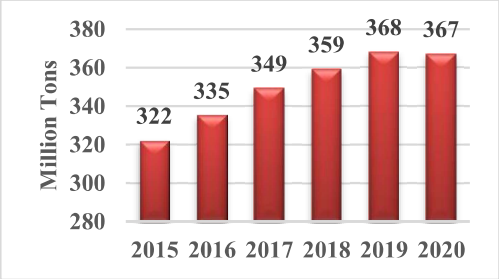

Figure-2. Global Polymer Production

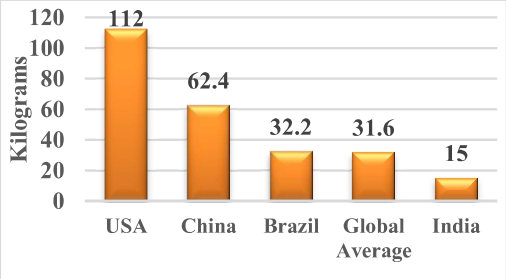

Figure-3. Per capita consumption of virgin polymer

In regards to the plastic production at world level, the Indian industries lags far behind the world's largest producer cum competitor "China" (Figure-4) whose actual contribution remained 32% of total global production in 2021. On technical manpower employment side, Indian polymer industries grew only at the pace of around 6.5 to 7.5% (Figure-5) during the last decade which need to be put on growth cycle.

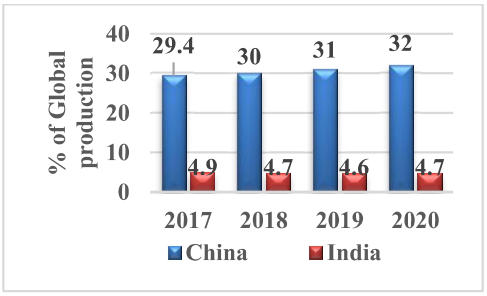

Figure-4. Global Production China Vs India

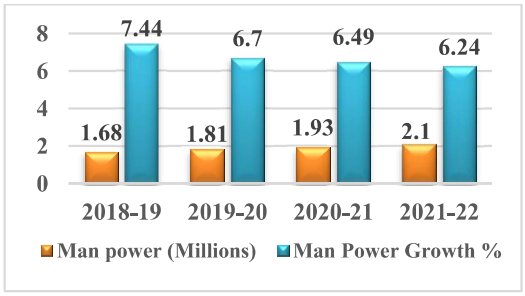

Figure-5. Technical manpower employed Vs Growth

The worldwide polymeric material market which came into existence during the period of World War II, stood at 589,902.9 million dollars in the year 2021, this is expected to

grow to 946,991.38 million dollars by 2030 at a CAGR of 5.4% (Prescient & Strategic Intelligence Pvt. Ltd., 2022). Several areas and new opportunity have now emerged in the Indian context to expend the research and development activity to match the production pace of countries ahead of us by creating new employment opportunities and increasing the per capita consumption.

1.2 Polymeric materials in the present-day electrical engineering field.

Unbeatable combination of characteristic such as ease of fabrication, low in density, light in weight, low-cost manufacturing, low energy processing, excellent chemical resistance and good mechanical strength have made polymers as one of the most desirable materials in engineering field. For application into electrical field, it requires incorporation of one or more characteristics such as high dielectric strength or excellent insulating or semiconducting or conducting or optical sensitivity by structural modification. In the last few decades, this wonder material become indispensable in electrical and other engineering (Matthews et al., 2021) field as crucial component for several key application as shown in figure 6.

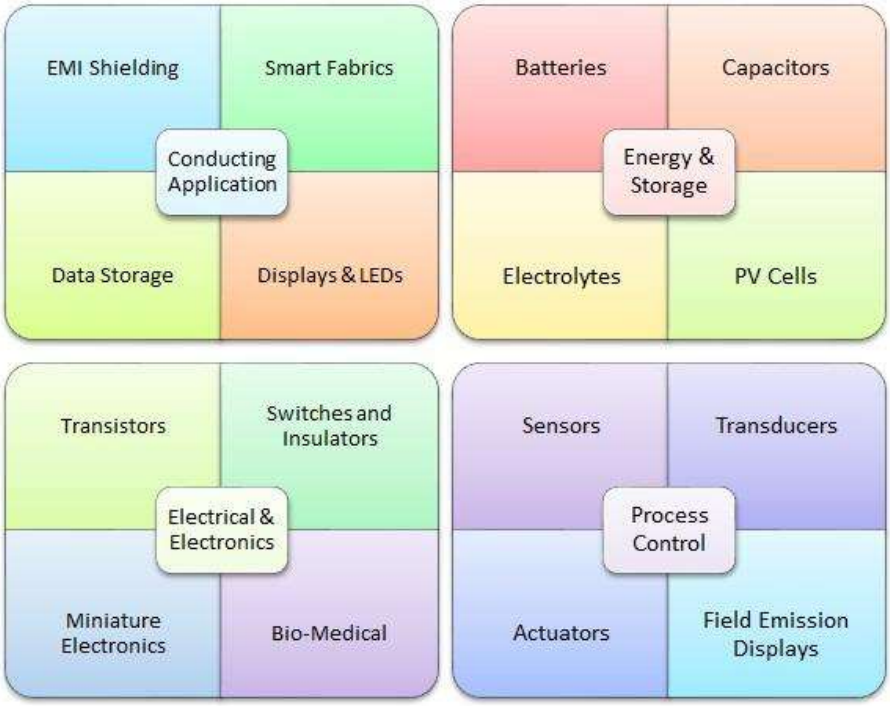

Figure 6. Polymeric application in electrical engineering field.

In advanced power system and electronic industry, polymeric materials were an obvious choice as potential substitute material for insulation and dielectric application owing to its capability to operate at high temperature and sufficiently high breakdown strength. Insulation belongs to a special class of materials which do not allow electricity to conduct through it, dielectrics are also a kind of insulating materials which do not conduct electricity but they store electricity when exposed to electric field. Energy stored in dielectric material can be released later in controlled manner for several electrical and electronic applications. Polypropylene (PP), Low density poly ethylene (LDPE), linear low density poly ethylene (LLDPE), high density poly ethylene (HDPE) and poly vinyl chloride (PVC), etc. are the key polymeric materials of interest for such electrical engineering applications.

Bakelite, a thermosetting resin developed in 1907 was the first complete synthetic polymer based electrical material used as insulation, which formed basis of electric relay or remote switch. Thereafter, electrical industry could not keep pace with the plastics industry. On analysis of report titled “Plastic -The facts 2016” on European Union (EU) plastic production, demand and waste as depicted in figure 7, it is revealed that, out of total polymeric demand of 49 mt in the year 2016, electrical and electronics industry consumed merely 5.8%.

Figure 7. European Union polymer market share in the year 2015 (PlasticEurope an Association of European Union Plastic Manufacturer, 2016).

Another global consultancy firm "ChemAnalyst" reported the percentage market share of consumed polymeric materials in electrical and electronic engineering field to be 12% (Figure 8) in year 2020 which is expected to grow upto 18.30% (Figure 9) in the year 2030 (ChemAnalyst.com, 2021).

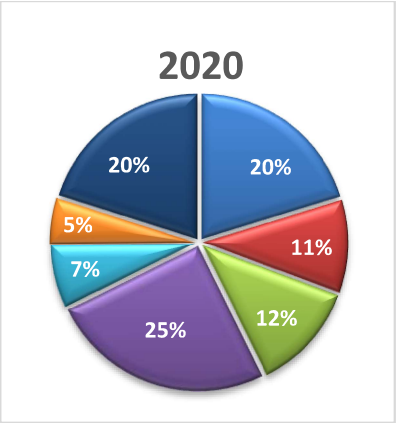

Figure 8. Polymer market share in 2020

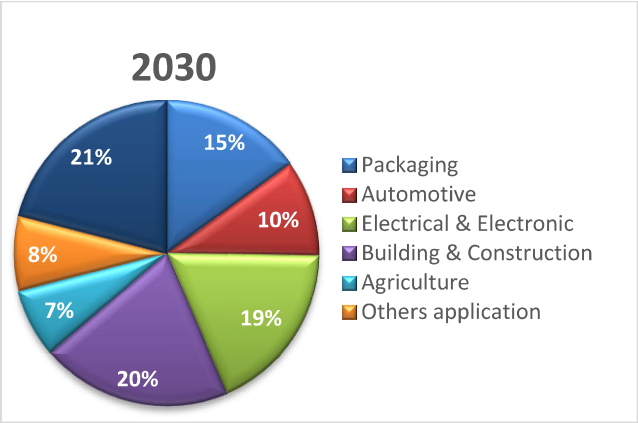

Figure 9. Projected polymer market share by Volume in the year 2030

Emergence of the electrical and electronics industry and the emergence of polymers as a new class of materials are both modern phenomena, both has grown with time but couldn't keep pace with each other. With the advent of newer polymeric materials of high performance, entire landscape in the industry has changed, this has created a favorable environment for academic research and development. Change in current industrial landscape can propel the total volumetric consumption of polymeric material in electrical field from 12% in 2020 to 19% (approximately) by year 2030 (ChemAnalyst.com, 2021).

1.3 Typical key characteristics of polymeric materials for electrical engineering field.

Despite of having several other applications of polymeric composite materials in the electrical engineering field, majority of application being consideration for studies in the present research are either insulating or dielectric, few examples are plastic coated wires, insulated terminals, insulated connector, industrial and house hold plugs, switches, encapsulation of microelectronics and dielectric materials as shown in figure 10.

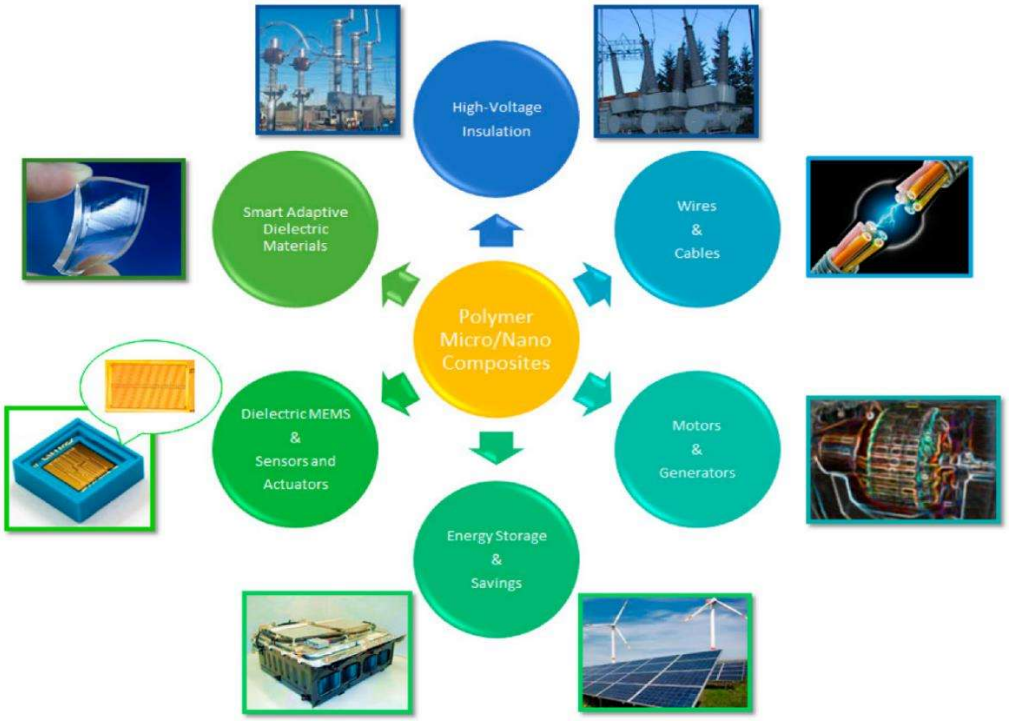

Figure 10. Polymeric Materials in Electrical Engineering Field
(Pleşa et al., 2016)

Although polymeric materials already possess one or more of the several electrical characteristics such as inherent electrical insulating property, deeply bound electric charge, permanent and induced electric dipole, piezoelectricity, pyroelectricity, photoemission, photoconductivity, etc., but they are weak in strength and intensity. Apart of these characteristics, followings are essentially required to be augmented through research work to determine its suitability in the electrical field as insulator or dielectric materials.

- High dielectric strength to withstand an electrical field between the conductors.
- Good arc resistance to prevent damage in case of arcing
- Ability to maintain integrity under a wide variety of environmental hazards such as humidity, temperature, and radiation.
- Mechanical strength strong enough to resist vibrations, shocks and other mechanical forces.
- High insulation resistance to prevent leakage of current across the conductors.

2 Literature Review.

(Feldman, 2008):- High molecules weight compound made from polymeric materials has existed at all times on earth's surface in its natural form. Protein and deoxyribonucleic (DNA) acid are two typical example of naturally available polymeric material. Plant fiber, carbohydrate, amino acids, wool, tortoise shells, amber, bee hive wax, animal horns, bones and sap from tropical trees etc. are few other commonly used polymeric compounds fulfilling the several day-to-day necessities of mankind. Although, role of natural polymer is ubiquitous in the everyday life of humankind and animal world, still, the word Polymer was presented as combination of two Greek words "poly" (meaning "many") and "mer" (meaning "unit") by a Swedish chemist "Jöns Jacob Berzelius" in 1833. He established himself as a pioneer in chemistry and is known for his unforgettable contribution and one of the founding members of the of modern chemistry. He presented the theory that benzene (C_6H_6) is a polymer of ethyne (C_2H_2).

(Feldman, 2008) (Burford & Emeritus, 2019) :- Till 1800 century, polymeric field was dominated by only natural polymers, until this period, area of synthetic polymers was unventured and unexplored. The later time of 19^{th} century, scientific adventures were done to replace the conventional material by cheaper and improved substitute of semi-natural polymeric material, thereafter, came the period of entirely synthetic polymers wherein raw materials were small molecules emerging out of coal and petroleum oil (Burford and Emeritus, 2019). The first man made plastic material named as "Parkeshine" was reported to be based on nitrocellulose, it was developed by Parkes in 1862 and modified by Hyatt in 1866. This was the first semi synthetic commercial plastic introduced to the world. Later on, phenol and styrene based aromatic compound was polymerized into nitrocellulose, addition of camphor to it led to a modified natural polymer known as celluloid. This was the first thermoplastic material which went into commercial production as movie film by 1900.

(J.A. Brydson, 1966) (Bakelizer, 1993) :- Year 1907 falls in the era which symbolizes the beginning of the true plastic age when first synthetic thermoset polymeric material was

synthesized by Belgian chemist named Leo Hendrik Baekeland, his experiment included phenol a disinfectant and formaldehyde resins for synthesis of a completely new material, this material was named as Bakelite which was commercialized in 1909-1910, this was a revolutionary product which formed the basis of industry which employs more than 60 million people today. Based on his discovery, Baekeland founded his company "Baekeland Corp" whose logo carried a statement **"The material of a Thousand Use"**.

(J.A. Brydson, 1966):- Until 1907, shellac varnish material (made of insect secretions found on south Asian trees) was the most popular choice for electronic insulation, thereafter, discovery of Bakelite was perceived as its suitable substitute which formed the basis of transition from natural to manmade polymer. Mechanical strength combined with flexibility in mouldability of new material and low-cost production capability paved the way for industrial revolution which resulted in products such as bases and sockets for electric light bulb, components of washing machine, automobile, spare parts to handset of telephone set and much more. By 1912, it became standard material for electrical insulating application. Soon after its launch in the market, Bakelite lost the interest of industrial fraternity due to it being very brittle in nature. Need of additive was thought of a way out to make it malleable and durable, but addition of additive was at the cost of surface disfiguration and discoloration in material. By that time, other plastic materials followed the markets which hold the color better then it, this led to abandoning of Bakelite.

(R. R. Kienle, 1949):- During the period following the year 1921, industrial researchers came up with new class of heat nonconvertible synthetic polymer called Alkyd resins or polyester polymers, the term Alkyd was first given by Kinle in 1927 to the materials formed by reacting polyhydric alcohols with polybasic and monobasic acids. These materials underwent several refinements over the period of research thereby displaying outstanding flexibility, durability, toughness, and excellent adhesive property. Although, development of Alkyd resins or polyester as new class of material was viewed as very important for electrical wire enamel industry but the interest was short lived because of concern due to color retention, after-tack, high acid value and low water resistance.

(Nuryawan et al., 2017; Ohalete and Popoola, 2019; Akinterinwa, 2020):- Urea formaldehyde resins (UF) also known as thermoset resins are synthesized using urea and formaldehyde as its constituent is known since 1915 but it went into commercial production after 1928 for binders in wood work. Although, such materials displayed good resistance to heat and electricity but still, it could not find its place as material of interest in the field of electrical industry because of its ability to absorb moisture and emission of formaldehyde a hazardous substance.

(S. S. Rogers, 1948; Amin and Amin, 2011):- Elastomer or Rubber are isoprene-based polymers with elastic properties to the tune of 300% or more, they exhibit good mouldability, resistance to electricity, fatigue resistance, corrosion and abrasion resistance, Natural rubber is extracted from a milk emulsion or latex of rubber producing tree called "Hevea Brasiliensis", it is a hydrocarbon polymer with a high molecular weight having formula (C5H8) x. Although, Natural rubber possesses high electrical insulation property but they deteriorate very easily on oxidization, they also suffer from high capacity to absorb water, low abrasion resistance, hydrocarbon solubility and sensitivity to acid and base both.

To overcome such shortcomings, artificial elastomer or synthetic rubber were synthesized from byproducts of petroleum industry. Buna-S-Rubber was the first synthetic rubber produced in United States of America during second world war. Thereafter, various other new material falling under the category of synthetic rubber came out of industrial research, they carried distinct advantage and disadvantages over its respective predecessor for application as electrical insulation materials. In 1960, ethylene-propylene-diene monomer (EPDM/EPM) was introduced which proved to be a failure, next phase of research (till 1980) brought ethylene-propylene co-polymer (EPR) followed by silicon rubber (SiR) into the market. Late 90's was christened as the age of thermoplastic elastomers (TPE), whose importance increased exponentially for application in electrical engineering field ranging from electronic device encapsulation to machine and cable insulation. Two major disadvantages offered by these materials are low thermal and chemical resistance and high cost of production.

(Spalding and Chatterjee Ananda M., 2017);- In 1898, Hans von Pechmann a German chemist and his colleagues reported the first known synthesis of polyethylene in laboratory, which was termed as “Polymethylene”. Later researchers at Imperial Chemical Industries presented the first commercial product under the trade name Low Density Poly Ethylene (LDPE). Later in 1960s and 1970s the manufacturing process underwent several evolutions whereby incorporation of new catalyst allowed the customization of PE characteristics such as density, flexibility, toughness, electrical resistivity and decaying tendency to suit the various industrial application.

(Mohamed, 2015) (Richardson, 2021):- As per the reports of Independent Commodity Intelligence Services, Polyethylene (PE) has emerged in the form of LDPE, HDPE (High Density Poly Ethylene) and its variants as the polymer with largest annual volume production projected to be around 118, 126, 132, 138 and 144 million tons in year 2021, 2022, 2023 2024 and 2025 respectively employing around 7 billion workforces. Continuous development of newer technology brought multiple reactors to modify the molecular structure of polymers to further tweak its characteristics as per the industry need, this opened a new horizon for researcher.

(Feldman, 2008; Greenway et al., 1999; Kato et al., 1994; Kurahashi et al., 2004; Yoshino et al., 2002; Zhang et al., 2003, 2002):- Upon blending of various polymeric materials with PE, investigation of their characteristics for suitability as high performing insulating polymers were presented in several studies. Although, blending of ethylene and propylene (EP) improved the Impulse breakdown strength of LDPE in high temperature region, still, various factors effecting the composition, morphology, additives and impurity of insulating polymers remained unknown (Mizuno et al., 1992). At operating temperature of 90 degrees, increase in EP content increased the impulse breakdown strength but its dc breakdown strength remained unaffected and elongation at break decreased sharply. Further mechanism of increase in impulse breakdown strength has not been well documented yet (Zhang et al., 2003).

(Kurahashi et al., 2004):- Another thermoplastic Polypropylene (PP) and its variants having higher melting temperature then PE were expected to exhibit potential of power

cables insulation material, but isotactic Polypropylene (iPP) proved to be unsuitable for this application owing to poor flexibility and very low breakdown strength due to growing spherulites, stereoregular syndiotactic polypropylene (s-PP) was proposed for such scenario, but, the properties of s-PP are still under observation. H-PP and c-PP the homopolymer and copolymer of polypropylene were also found to be unsuitable for the power cable insulation application because of increased electrical conductivity due to accelerated space charge distribution, improved charging current and copolymerization of ethylene (Nakane ' et al., 2005).

(Yui et al., 2006):- An investigation into the influence of high-density polyethylene (HDPE)/polypropylene (PP) content in blends with carbon Black (CB) and viscosity of PP revealed that electrical resistivity decreased with increased HDPE content but increase in resistivity was observed with increased viscosity of PP matrix.

(Shin et al., 2009):- To reduce the production cost, enhance the mechanical and electrical characteristics and reinforce the polymer matrix in polymeric materials, filler materials and nano-materials were introduced into the polymeric composite which resulted in new class of materials with superior dielectric strength, mechanical strength and superb chemical properties. It was observed that, as the amount of nano filler of size 12-15 nm was increased beyond 0.4 wt%, particle lump was observed which deteriorated the dielectric strength of specimen because of increase in number of interfaces.

(Amin and Amin, 2011b; Lau and Piah, 2011):- Despite of having keen interest of researchers in polymeric nanocomposite for its high electrical insulating property, still, there is lack of substantiative data to validate the evidence of enhanced dielectric properties of polymer nanocomposite in regards to the interfacial area.

(Rogti and Ferhat, 2014):- The feasibility of LDPE and fluorinated ethylene propylene as two dielectric film based multi-dielectric structure too was explored and it was observed by the researcher that with increase in temperature the conductivity of the dielectric specimen under investigation increases, this causes the increased mobility of charge carriers making it unsuitable for insulating application.

(Dabbak et al., 2018; Green et al., 2015; Lee et al., 2012; Paramane & Kumar, 2016):- Due to excellent electrical breakdown strength, crosslinked polyethylene (XLPE) appeared to be potential candidate for insulation material, but its major drawback is environmental issues. Because of its thermosetting ability, it is difficult to be recycled after removal from service. Need of the hour is an environmentally friendly non-crosslinked PE and PP materials having potential of reusability. There exists a lack of lab result comparison of crosslinked polyethylene (XLPE) specimen vis-s-vis its field trial. Non-standardization of preparation methods, change in polymer structure and its surface degradation are few other bottlenecks for further fruitful research in this field.

(Pleşa et al., 2019);- Polymer nanocomposites often exhibit the reduced permittivity, particularly at lower frequency. Large negative slope is also found at both the real permittivity and tan delta. Very little knowledge exists regarding lifetimes of nanocomposites and its long-term toxicity.

(Ghorbani et al., 2017):- Summary of results of several studies pointed towards the fact that DC conductivity of PP, LDPE and XLPE slowly decays sub-linearly with time in high field region. this phenomenon was found to be independent of the voltage.

(Cao et al., 2017):- Addition of MgO nanofiller in PP resulted in improved dc breakdown strength particularly at low nano MgO concentration, an increase in permittivity with increasing temperature was also observed at first which decreased thereafter. Suppression property of deterioration of electric field also deteriorated when nanofiller concentration reached as high as 6 wt%.

(Wei et al., 2019):- Addition of graphene nanosheets in HDPE-LDPE or PP-LDPE blends affected the conductivity of polymeric blends by affecting the crystal size. For the smaller crystal size, crystalline part has larger surface area which lead to large trap or lower conductivity and vice versa.

(Meng et al., 2019):- From environmental consideration, recyclable thermoplastic materials were seen as future trend for electrical insulation application as a substitute of crosslinked polyethylene (XLPE). As a perspective substitute, Polypropylene block

copolymer (PPB) and polypropylene random copolymer (PPR) with different weight-averaged molecular weight (Mw) were explored wherein PPB exhibited low DC breakdown strength, brittleness and poor mechanical property whereas high modules of PPR under room temperature too appeared as an adverseness which needs optimization.

(Ouyang et al., 2020):- The blend of PE and PP too were seen as potential recyclable composite as alternative electrical insulation material but poor compatibility of both the material with each other posed great difficulty which needs to be overcome.

(Sun et al., 2020):- Ungrafted acrylic acid (AA) monomer in graft copolymers were synthesized by researcher through pre irradiation and melt extrusion grafting, linear low-density polyethylene-grafted AA (LLDPE-g-AA) was thus obtained. The investigation revealed that the influence of Ungrafted AA on dielectric strength weakened whereas polyacrylic acid (PAA) played a key role in increasing the dielectric strength.

(Yu et al., 2020):- Yet in another study, blend of PP with ethylene-1-octane copolymer (EOC) and ethylene-propylene random copolymer (rPP) was synthesized, its mechanical and electrical characteristics were found to be stable even upto 110 degrees centigrade, but the comprehensive mechanism of correlation between the structural and electrical properties still remains unanswered.

(Nilsson et al., 2021):- Composites of semiconducting nanoparticle C_8-Al_2O_3, HDPE and LDPE were synthesized and characterized and investigated, in another study, low density polyethylene grafted PS graft copolymer (LLDPE-g-PS) was synthesized and blended with LLDPE to obtain LLDPE/LLDPE-g-PS blend (Sun et al., 2021). In another study, a blend of small amount of polystyrene-b-poly(ethylene-co-butylene)-b-polystyrene (SEBS) with LDPE and isotactic PP (i-PP) too was synthesized and characterized (Ouyang et al., 2021). The result so obtained during investigation of all the samples were very encouraging with substantial decrease in electrical conductivity, still the ample opportunity exists to further optimize the polyethylene blend, filler materials and nanoparticle independently to further improve its electrical insulating property (Nilsson et al., 2021).

(Uyor et al., 2022):- In a study, BN-BaTiO3-BN sandwiched nanoparticle in PP matrix was synthesized, in another study, nanocomposite of Polyvinyl alcohol (PVA)-Polymer containing enteric ether mixture (PEO) with strontium titanate ($SrTiO_3$) and cobalt oxide (CoO) nanoparticles (PVA - PEO - $SrTiO_3$ - CoO) was also investigated and evaluated (Mahdi and Habeeb, 2022), it was observed that the dielectric constant and dielectric loss reduces with increasing frequency and increases on increase of nanoparticle concentration due to interfacial polarization (Mahdi and Habeeb, 2022). Nanocomposite of biaxially oriented polypropylene (BOPP) and nano TiO2 was evaluated in yet another study (Zhang et al., 2022) for its electrical property wherein it was observed that the permittivity of the nanocomposite was enhanced to great extent but such enhancement was sensitive to stretching ratio.

(Prateek and Gupta, 2022):- Rapid pace of industrialization at world level has led to increased focus of industries towards low cost, biodegradable, environment friendly, recyclable and new range of polymeric materials for industrial application and sustainable devolvement. This triggered the race among the researchers for development of natural bio-composite for electrical insulation material which should be based on renewable source rather than non-renewable counterpart.

(Doddashamachar et al., 2022; Fares et al., 2022):- Demand of such environment friendly composite material for low electrical conductivity application resulted in polypropylene composite reinforced by natural fiber extracted from lignocellulose fibers of several naturally available materials such as black pepper, sumac, pomegranate, lemon (Fares et al., 2022) and banana (Doddashamachar et al., 2022), such studies mainly focused on the role of coupling agent rather than its dielectric property, evaluation of electrical property in comparison to industrial insulation/dielectric materials in practice still remains unexplored.

3 Description of Broad Area.

Because of its ability to perform varied functions based on its versatile characteristics, emerging thermoplastic and thermoset polymeric materials and their composites are

increasingly and more frequently being replacing the conventional electrical materials in wide range of electrical engineering applications now a days. The main reason for this trend is the amazing characteristics of the polymeric materials, which enables the design engineers and product manufactures to come up with vast range of products to meet real life several applications at acceptable market price and production margin.

Until recently, polymers were considered a relatively weaker material in terms of load bearing properties at raised temperatures. This limited the use of polymers in electrical application to non-load bearing and general-purpose applications. Their utility as insulation too were limited as thick insulation material to cater for increase in high operating voltages. Simply, increasing the thickness of insulating material to accommodate the elevated voltage level is not a practical and feasible solution for manufacturing miniaturized high power electronic components. With miniaturization of components in modern electronic equipment and high-power industry and emergence of polymeric hybrid composite as new class of material, new opportunity has emerged in research and development field to tweak the ability of polymeric materials at molecular level such as to withstand the high temperature condition and display properties such as, high dielectric/electric stress, high thermal conductivity and high mechanical strength even at lower thickness and weight. The modern electrical engineering application of these materials requires thermally conductive insulating or dielectric material non-reactive to naturally occurring environmentally induced chemical activity. Industrial research has increased its focus towards low cost, biodegradable, environment friendly, recyclable and new range of polymeric materials for industrial application and sustainable devolvement. This has taken center stage because of environmental aspect being kept alongside sustainability for industrial growth. Industrial advancement at the cost of ecological damage is neither warranted nor sustainable in the long run, this has triggered the race among the researchers for development of reusable polymeric hybrid composite and natural polymeric bio-composite materials for engineering production which includes electrical insulation material also. Such materials are expected to be an outcome of a renewable source rather than non-renewable counterpart as far as possible.

4 Objective of the study.

The scope of the proposed research/study/work is **"**Synthesis and characterization of polymeric composites for electrical engineering applications**".** The composites of different polymeric materials reinforced with filler of inorganic and/or organic nature will be synthesized by reactive melt blending techniques (Alam, 2018), keeping this in view the main objectives of the present study are.

a) To synthesize the polymeric composites and optimize its filler content for optimal electrical behavior.
b) To investigate the electrical, mechanical and chemical properties of the developed composite materials and perform its characteristics optimization.
c) To study the effect of fillers concentration on the electrical, physio-chemical, mechanical and thermal properties.
d) To find suitable applications of the developed composite material in the electrical engineering sector.

5 Methodology.

The following characterization techniques will be used to establish the findings of the proposed research work:

a) Synthesize and optimize the percentage of fillers in polymeric composite using reactive melt blending for optimal electrical behavior.
b) Physio-chemical Properties using: Fourier transform Infrared (FTIR) spectroscopy and Attenuated Total Reflectance (ATR) sampling methodology.
c) Crystallization Behavior of newly synthesized material using: Differential Scanning Calorimetry (DSC) and X-ray Diffraction (XRD) analysis.
d) Electrical Properties using: Insulation resistance, dielectric strength, Arcing resistance

e) Mechanical Properties using: Tensile strength, Flexural Strength, Elongation and Youngs Modulus etc.

6 Expected Outcome of the Research.

It is expected that, on the completion of proposed research work, an environment friendly polymeric composite will be synthesized for the industrial application such as electrical Insulation or dielectric material. Material so obtained may be expected to exhibit superior electrical properties, physio-chemical stability, thermal resistance and mechanical strength. A suitable application for the electrical field is also an expected outcome from this study.

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